Fabrication of White Organic Light-Emitting Devices with a Double-Doped Emissive Layer

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Abstract *Efficient white light emission with mixing of red emission from Iracac [bis(2-2'-benzothienyl) pyridinato-N,$C^{3'}$) (acctylacetonate) iridium(III) green and blue from derivative of Iridium picolate (FIrPic) [Bis(2-(4,6-difluorophenyl)pyridinato-N,$C^{2'}$)picolinate iridium(III)] is reported. Iracac and FIrPic are codoped into a 4,4' bis 9 carbozyl (biphenyl)(CPB) host. The device emission colour is controlled by varying dopant concentrations. PL, EL and colour coordinates were studied. The EL spectra of the devices with a double-doped emissive layer show three emission peaks at 469 nm, 500 nm and 611 nm. CIE coordinates of the device are (0.24, 0.35) at 18 V and are well within the white region.*

Keywords: White OLED; iridium complexes.

Introduction

During the last few years, organic electronic devices are being developed for several potentially important applications e.g. Organic thin film transistors, Organic light emitting diodes and Organic photovoltaic devices. Organic light emitting diodes technology is considered as a direct replacement for LCD displays where all emission colors are equally important. They are also being considered for replacement of incandescent lamps for general illumination where good quality white light is of quite important. White OLEDs which have broadband emission, are suitable for application in full color displays which uses optical filters for getting the required color. Intense research all over the world during the last few years have developed intense blue, green and red organic LEDs which have been used by many researchers for white light generation by mixing colors. The efficiency of these devices is 20% higher than the incandescent lamp and reported working life of device exceeds 50,000 hours as compared to the life of 1,000 hours for incandescent lamps. Considerable success has been achieved in recent years in the development of the WOLED based on phosphorescent materials [1-11]. They include using blue, yellow and red phosphor doped emissive layers combined in a device [1], using a phosphorescent excimer [2] and by using new phosphorescent sensitizers [3,4] to obtain white light emission. Kido *et al* [5] reported WOLEDs using polymer doped with three fluorescent dyes. D'Andrade *et al* [6] have reported electro phosphorescent WOLEDs with a triple doped emissive layer. Gao et al [7] have obtained WOLEDs by employing a hole-transporting layer of mixed light-emitting organic materials. Green and red phosphorescent light-emitting devices based on fac (2-phenylpyridine) iridium [Ir(ppy)3] [8–11] and bis (1-(phenyl)isoquinoline) iridium (III)acetylanetonate [Ir(piq)2(acac)] [12] have been reported.

In the present work, we have premixed different emitter materials in suitable ratio so as to get white light emission from the organic LED devices. Highly efficient iridium complexes were used as emitters in the present work. Fluorine derivative of Iridium picolate (FIrPic) [Bis(2-(4,6-difluorophenyl)pyridinato-N,$C^{2'}$)picolinate iridium(III)] were used as guest molecule and 4,4' bis 9 carbozyl (biphenyl)(CPB) as host. A small percentage of Iracac [bis(2-2'-benzothienyl)pyridinato-N,$C^{3'}$)(acctylacetonate)iridium(III) was used as dopant for modulation the color of the devices. BCP (2,9 dimethyl 4,7 diphenyl 1,10 phenanthrolene) was the hole blocking material. A suitable combination of charge carrier transport material containing α-NPD with suitable dopants, emitter and electrode materials were used to fabricate white light emitting diodes. A White OLED fabricated using the above procedure is shown in Fig 1.

Experimental details

Organic layers were deposited by high-vacuum (10^{-6} Torr) thermal evaporation the required organic material onto a cleaned indium tin oxide (ITO) coated glass substrate. The layer thickness of the deposited material was monitored using a quartz crystal thickness monitor. Finally a LiF buffer layer and Al cathode were vapour deposited onto organic films. The structure of the devices is ITO/α-NPD(30nm) /CBP:FIrPic:Iracac (25 nm)/BCP(6nm)/ Alq_3(28 nm)/LiF(1nm)/Al(100nm). Tris (8-hydroxyquinoline) aluminium (Alq_3) and α-NPD was used as the electron and hole transporting layers. Ir(acac) and FIrPic are co-doped into the wide energy gap CBP host. The concentration of the Ir(acac) is 0.5 and 0.25 wt% and that of the FIrPic is 5 wt% in the two devices. EL spectra and CIE co-ordinates of the devices were measured by an ocean optics HR-2000CG UV-NIR spectrophotometer and the current–voltage–brightness characteristics were simultaneously measured by a Keithley 2400 programmable voltage–current source and Luminescence meter(LMT 1009). All measurements were carried out at room temperature under ambient conditions.

Results and discussion

Fig.1 shows the white OLED with configuration, ITO/(NPD(30nm)/CBP:Iracac:FIrPic(25nm) /BCP(6nm)/Alq3(28nm)/ LiF(1nm)/Al(100nm).In these devices, doping concentration of Ir(acac) is 0.5wt%. Photoluminescence spectrum of CBP, FIrpic and Iracac thin films are shown in Fig 2. The emission peaks are observed at 380nm, 494nm, 510nm and 620nm respectively.

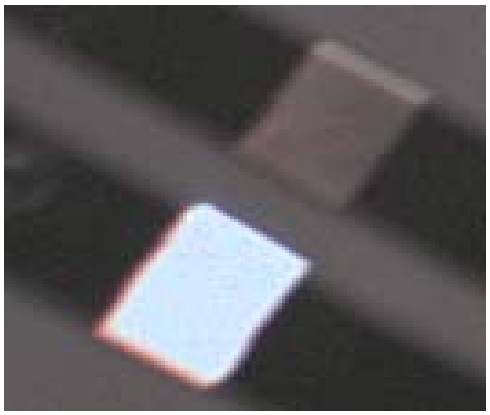

Figure 1. Fabricated White OLED

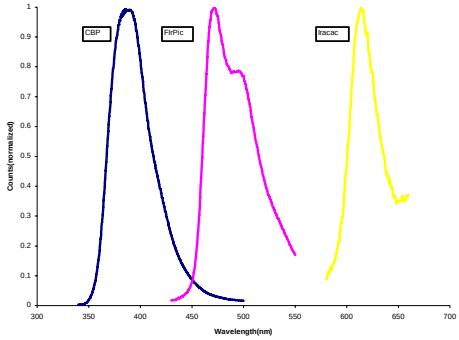

Figure 2. Normalized PL spectra of CBP, FIrPic and Iracac

Fig 3. Shows the normalized EL spectra of the devices with doping concentrations of (a) 5 wt% FIrPic (b) 0.5 wt% Iracac in CBP, and (c) 5 wt% FIrPic and 0.5 or (d)5wt% FirPic and 0.25 wt% Iracac in CBP at 11 volt. The EL spectra of the devices with a double-doped emissive layer show three emission peaks at 469 nm, 500 nm and 611 nm. The devices colors are changed form yellowish to bluish white as the voltage increases. The CIE coordinates of the device at 11V is (0.26, 0.33). The CIE coordinates of these two devices are well within the white region. More work will be required for optimizing the device properties.

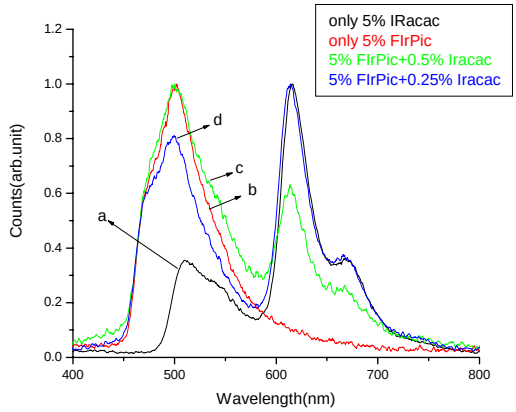

Figure 3. EL spectra of the two control devices(a&b) and the devices with a double-doped emissive layer(c&d).

The luminance-voltage –current characteristics for the white device are illustrated in Fig 4. The turn- on voltage is slightly higher (~9V). The luminance increases linearly with the increasing voltage. The white OLED with CIE coordinates x=0.25,y=0.32, reaches a maximum luminance of 300cd/m^2 at 18V.

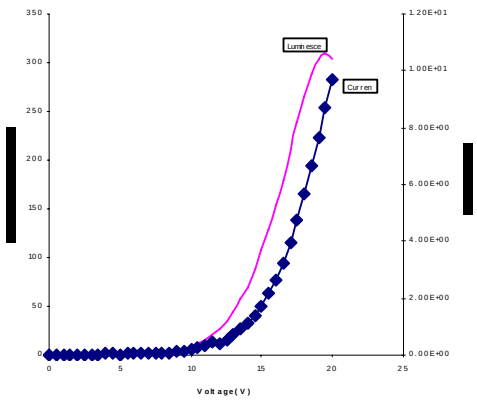

Figure 4. Luminance-voltage-current curves for the white OLED

Conclusion

In summary, we have fabricated high-efficient electrophosphorescent white organic light-emitting devices with a double-doped emissive layer. FIrPic and Iracac are co-doped into the CBP host. Varying dopant concentrations controls the colour of the device. The maximum luminance of the device is 300cd/m^2. The CIE coordinates of the device are (0.24, 0.35) which is well within the white region and can be improved by proper optimization.

Acknowledgements

The authors (RS) would like to thank Dr. Vikram Kumar director NPL for his interest in this work. Also thanks to Dr. Anil Gupta for their help and co-operation.

References

1. D'Andrade B W, M E Thompson and S R Forrest, "Controlling Exciton Diffusion in Multilayer White Phosphorescent Organic Light Emitting Devices" *Adv. Mater.* **14** 147, 2002.

2. D'Andrade B W, J. Brooks, V. Adamovich, M E Thompson and S R Forrest, "White Light Emission Using Triplet Excimers in Electrophosphorescent Organic Light-Emitting Devices", *Adv. Mater.* **14,** 1032, 2002.

3. Li F, G Cheng, Y Zhao, J Feng, S Y Liu, M Zhang, Y G Ma and J C Shen, "White-electrophosphorescence devices based on rhenium complexes", *Appl. Phys. Lett.***83** 4716,2003.

4. Cheng G, F Li, Y Duan, J Feng, S Y Liu, S Qiu, D Lin, Y G Ma and S T Lee, "White organic light-emitting devices using a phosphorescent sensitizer", *Appl. Phys. Lett.* **82** 4224, 2003.

5. Kido J, W Ikeda, M Kimura and K Nagai, "White-Light-Emitting Organic Electroluminescent Device Using Lanthanide Complexes" *Japan. J. Appl. Phys.* **35** L394, 1996.

6. D'Andrade B W, R J Holmes and S R Forrest, "Efficient Organic Electrophosphorescent White-Light-Emitting Device with a Triple Doped Emissive Layer", *Adv. Mater.* **16** 624, 2004.

7. Gao Z Q, C S Lee, I Bello and S T Lee "White light electroluminescence from a hole-transporting layer of mixed organic materials", *Synth. Met.* **111–112,** 39, 2000.

8. M A Baldo, S Lamansky, P E Burrows, M E Thompson and S R Forrest "Very high-efficiency green organic light-emitting devices based on electrophosphorescence", *Appl. Phys. Lett.* **75,** 4, 1999.

9. Tsutsui T, M J Yang, M Yahiro, K Nakayama, T Watanabe, T Tsuji, Y Fukuda, T Wakimoto and S Miyaguchi, "High Quantum Efficiency in Organic Light-Emitting Devices with Iridium-Complex as a Triplet Emissive Center"**,** Japan. *J. Appl. Phys.* **38** L1502, 1999.

10. Adachi C, M A Baldo and S R Forrest "High-efficiency organic electrophosphorescent devices with tris(2-phenylpyridine)iridium doped into electron-transporting materials" *Appl. Phys. Lett,.* **77,** 904, 2000.

11. Adachi C, M A Baldo, M E Thompson and S R Forrest "Nearly 100% internal phosphorescence efficiency in an organic light emitting device", *J. Appl. Phys.* **90,** 5048, 2001.

12. Su Y J, H L Huang, L Li C, C H Chien, Y T Tao, P T Chou, W Datta and R S Liu, "Highly Efficient Red Electrophosphorescent Devices Based on Iridium Isoquinoline Complexes: Remarkable External Quantum Efficiency Over a Wide Range of Current", *Adv. Mater.* **15** 884,2003.